US010470841B2

(12) United States Patent
St-Jean et al.

(10) Patent No.: US 10,470,841 B2
(45) Date of Patent: Nov. 12, 2019

(54) ROBOT-BASED RACK PROCESSING SYSTEM

(71) Applicant: **STERIS Inc.**, Temecula, CA (US)

(72) Inventors: **Hugo St-Jean**, Quebec (CA); **Daniel Rochette**, Quebec (CA)

(73) Assignee: **STERIS Inc.**, Temecula, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 39 days.

(21) Appl. No.: **15/471,071**

(22) Filed: **Mar. 28, 2017**

(65) **Prior Publication Data**

US 2018/0280112 A1 Oct. 4, 2018

(51) **Int. Cl.**

A61B 90/70 (2016.01)
B08B 13/00 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***A61B 90/70*** (2016.02); ***B08B 13/00*** (2013.01); ***G05D 1/0297*** (2013.01); *A61B 50/22* (2016.02);

(Continued)

(58) **Field of Classification Search**

CPC A61B 1/125; A61B 2017/003; A61B 2034/301; A61B 34/25; A61B 34/30; A61B 34/37; A61B 34/71; A61B 1/123; A61B 2017/00243; A61B 2034/715; A61B 17/062; A61B 2017/00238; A61B 2017/00336; A61B 2017/00743; A61B 2017/00805; A61B 2034/105; A61B 2034/107; A61B 2034/2015;

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,742,738 A * 7/1973 Frotriede D06F 95/00 68/210
4,328,422 A 5/1982 Loomer 250/239

(Continued)

FOREIGN PATENT DOCUMENTS

CA 2398942 A1 * 8/2001 .... A61B 1/00057
DE 20023832 U1 11/2006

(Continued)

OTHER PUBLICATIONS

Website print out of "Adept Mobile Products," Adept Lynx Omron Adept Technologies, Inc., http://www.adept.com/products/mobilerobots/mobileplatforms/lynx/general, printout date, Mar. 3, 2017.

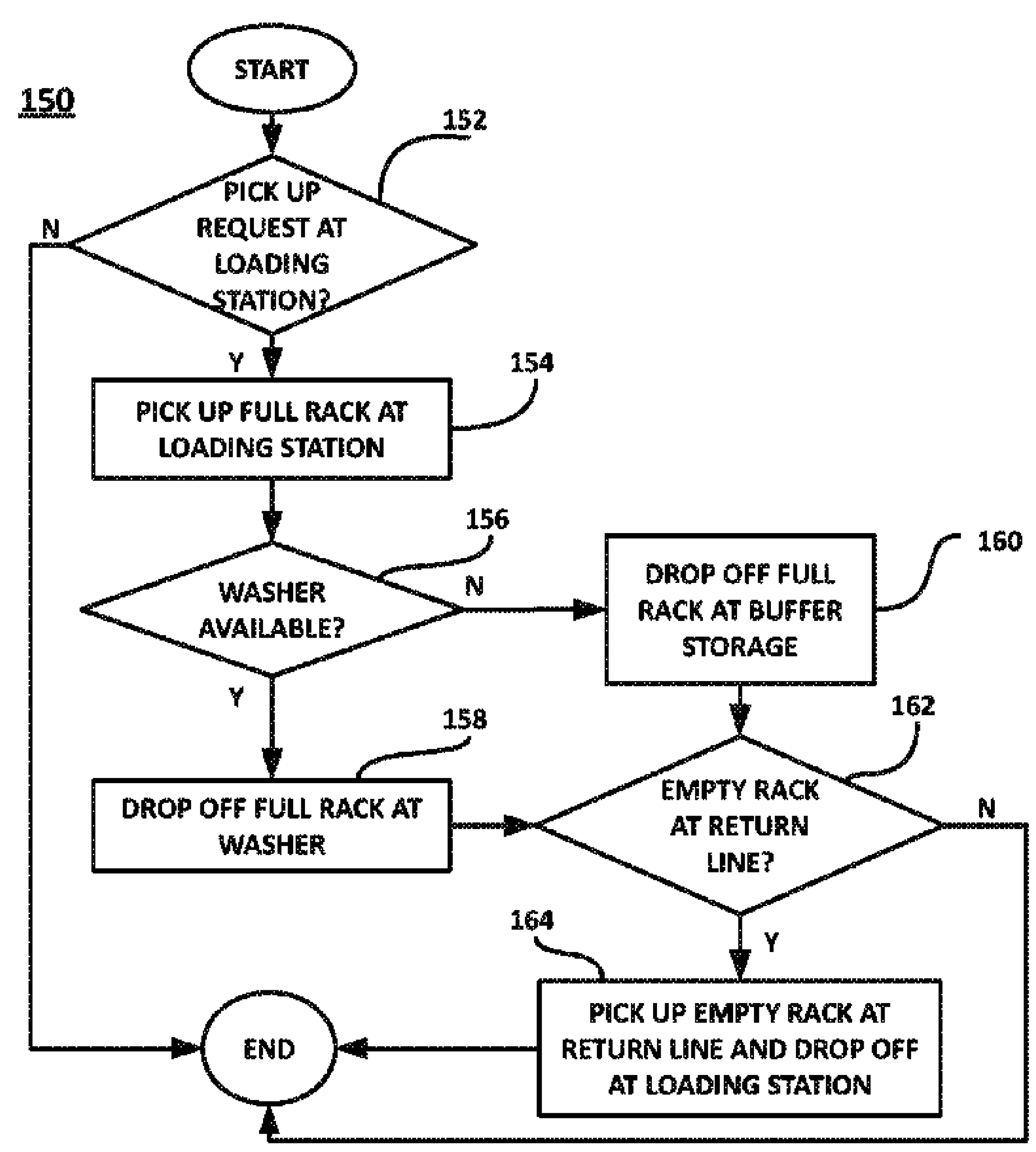
(Continued)

Primary Examiner — Alexander G Kalinowski
Assistant Examiner — Sanjeev Malhotra
(74) *Attorney, Agent, or Firm* — Kusner & Jaffe

(57) **ABSTRACT**

A robot-based system for processing racks used for transportation of articles in connection with an inactivation procedure, such as sterilization, disinfection, and decontamination. Robots are used to move full and empty racks between a plurality of a locations within soiled and clean areas of a workspace, including, but not limited to, a loading station where soiled medical instruments are loaded on the racks, washer/disinfectors for processing the medical instruments, and an unloading station where clean medical instruments are unloaded from the racks for sorting into trays.

6 Claims, 6 Drawing Sheets



(51) **Int. Cl.**
G05D 1/02 (2006.01)
A61B 50/22 (2016.01)

(52) **U.S. Cl.**
CPC *G05D 2201/0206* (2013.01); *Y10S 901/01* (2013.01)

(58) **Field of Classification Search**
CPC A61B 2090/364; A61B 2090/376; A61B 2090/378; A61B 34/20; A61B 46/10; A61B 50/13; A61B 8/0808; A61B 90/361; A61B 17/0469; A61B 17/0482; A61B 17/1114; A61B 18/08; A61B 1/00057; A61B 1/018; A61B 1/2676; A61B 1/273; A61B 2017/00296; A61B 2034/102; A61B 2034/2063; A61B 2034/256; A61B 2034/303; A61B 2090/035; A61B 2090/062; A61B 2090/065; A61B 2090/3784; A61B 34/74; A61B 34/76; A61B 5/0006; A61B 5/053; A61B 5/7285; A61B 6/541; A61B 8/12; A61B 90/39; A61B 90/50; A61L 2/24; A61L 2/22; A61L 2202/17; A61L 2202/24; A61L 2/18; A61L 2/186; B33Y 80/00; B33Y 70/00; G01N 35/04; G01N 2035/041; G01N 1/31; G01N 2035/00542; G01N 2035/00851; G01N 2035/0465; G01N 21/78; G01N 33/54386; G01N 35/00623; G01N 35/00732; G01N 35/0092; G01N 35/0099; G01N 35/026; G01N 35/028; G01N 19/00; A61M 25/0133; A61M 2025/0004; A61M 25/0105; A61M 25/0147; B01L 2200/025; B01L 2300/021; B01L 2300/022; B65B 3/003; B65B 31/02; B65B 31/024; B65B 55/16; B65B 59/00; A01B 35/32; A01B 76/00; A61J 1/20; A61J 3/002; B01F 11/0008; B01F 11/0017; B01F 13/0094; B01F 13/1055; B01F 13/1063; B01F 15/00253; B08B 3/02; B25J 11/0085; B25J 5/02; B25J 9/023; B25J 9/1676; B25J 9/1689; G05B 2219/40202; G05B 2219/40425; G05D 1/0265; G05D 2201/0208; G07F 11/002; G07F 11/165; G07F 11/70; Y10S 435/809; Y10S 436/809; Y10S 901/02
USPC 700/226, 230, 239, 245, 248, 299; 73/863.81; 422/28, 50, 65; 435/5, 6.19; 436/47; 414/217, 222.01; 606/1; 134/18, 25.2, 102.2, 161; 172/1; 141/37; 600/106, 407; 424/700; 294/213; 105/156; 296/19; 165/11.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,500,970 A 2/1985 Daemmer 364/513
4,679,152 A 7/1987 Perdue 364/513
5,211,523 A 5/1993 Andrada Galan et al. 414/282
5,279,672 A 1/1994 Betker et al. 134/18
5,756,304 A * 5/1998 Jovanovich C12Q 1/04 422/50
6,082,799 A * 7/2000 Marek B60P 3/14 296/19
6,278,917 B1 8/2001 Bauer et al. 701/23
6,558,620 B1 * 5/2003 Sanford A61B 1/123 134/102.2
6,582,654 B1 * 6/2003 Kral A61B 1/123 134/161
6,959,714 B1 11/2005 Håkansson et al. 134/25.2
7,114,907 B2 10/2006 Ogawa et al. 414/744.5
7,133,746 B2 11/2006 Abramson et al. 700/259
7,306,423 B2 12/2007 Ogawa et al. 414/749.1
7,708,517 B2 5/2010 Nakamura et al. 414/816
7,809,470 B2 10/2010 Shoenfeld 700/243
7,850,414 B2 12/2010 Uratani et al. 414/744.2
7,996,109 B2 8/2011 Zini et al.
8,272,830 B2 9/2012 Kurita et al. 414/749.5
8,532,817 B2 9/2013 Bacom et al. 700/214
8,721,984 B2 5/2014 Carbone et al. 422/292
8,795,593 B2 8/2014 Nichols et al. 422/63
8,948,914 B2 2/2015 Zini et al. 700/258
9,358,688 B2 6/2016 Drew 52/747
9,360,300 B2 6/2016 DiBernado et al. 356/614
9,422,108 B2 8/2016 Hognaland B65G 1/0464
9,489,490 B1 11/2016 Theobald G06F 19/3462
2002/0001537 A1 * 1/2002 Hlebovy A61B 1/00057 422/28
2005/0038556 A1 * 2/2005 Gagnon A61B 90/90 700/226
2005/0166860 A1 * 8/2005 Austin A01K 1/031 119/458
2006/0178776 A1 * 8/2006 Feingold G01N 35/0092 700/245
2006/0276775 A1 * 12/2006 Rosenberg A61B 17/00234 606/1
2007/0043338 A1 * 2/2007 Moll A61B 34/71 606/1
2007/0071832 A1 * 3/2007 Kral A61B 1/125 424/700
2007/0081881 A1 * 4/2007 Okuno H01L 21/67167 414/217
2007/0099189 A1 * 5/2007 Gomez-Elvira Rodriguez G01N 1/31 435/6.19
2007/0197896 A1 * 8/2007 Moll A61B 1/00039 600/407
2010/0043834 A1 * 2/2010 Scheringer A47L 15/241 134/25.2
2010/0126286 A1 * 5/2010 Self G01N 35/04 73/863.81
2010/0129789 A1 * 5/2010 Self B01L 9/06 435/5
2010/0203643 A1 * 8/2010 Self B01L 9/06 436/47
2011/0067781 A1 * 3/2011 Osborne B65B 3/003 141/37
2011/0156417 A1 * 6/2011 Weber B65G 45/00 294/213
2011/0208350 A1 * 8/2011 Eliuk A61J 1/20 700/240
2011/0262250 A1 * 10/2011 Treat A61L 2/22 414/222.01
2011/0262319 A1 10/2011 Svensson
2011/0295423 A1 * 12/2011 Anderson G05D 1/0088 700/248
2011/0295424 A1 * 12/2011 Johnson A01D 34/008 700/248
2012/0028342 A1 * 2/2012 Ismagilov B01L 3/502738 435/283.1
2012/0065467 A1 * 3/2012 Moll A61B 8/12 600/106
2012/0291808 A1 * 11/2012 Monsrud B08B 3/02 134/18
2013/0184849 A1 7/2013 Chan 700/113
2014/0014292 A1 * 1/2014 Rice H05K 7/20836 165/11.1
2014/0144470 A1 * 5/2014 Sewell B01F 3/04503 134/18
2014/0241946 A1 * 8/2014 Self G01N 35/04 422/65
2014/0246257 A1 9/2014 Jacobsen et al. 180/14.2

(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0365258	A1	12/2014	Vestal et al.	705/7.15
2015/0241458	A1*	8/2015	Pollack	G01N 35/00623 700/230
2015/0250678	A1*	9/2015	Eliuk	A61J 1/20 700/239
2015/0273691	A1*	10/2015	Pollack	G01N 35/00623 348/143
2015/0337400	A1*	11/2015	Wilson	G16B 99/00 700/299
2015/0351309	A1*	12/2015	Gaus	A01B 51/023 172/1
2016/0158942	A1	6/2016	Augenbraun et al.	700/253
2016/0235879	A1	8/2016	Andersson et al.	
2016/0236869	A1	8/2016	Kimura et al.	B65G 1/1378
2016/0288121	A1*	10/2016	Ismagilov	B01L 3/502738
2017/0086929	A1*	3/2017	Moll	A61B 8/12
2017/0251589	A1*	9/2017	Tippery	A01G 22/00
2018/0036889	A1*	2/2018	Birkmeyer	A47L 15/4293
2018/0318458	A1	11/2018	Rasmussen	

FOREIGN PATENT DOCUMENTS

DK	201600071	U3	2/2017	
WO	WO-2007089269	A2 *	8/2007	B25J 5/02
WO	WO-2016009204	A1 *	1/2016	A61B 50/34
WO	WO-2017163251	A2 *	9/2017	B25J 9/1676

OTHER PUBLICATIONS

KEN Hygiene Systems, Automated Logistics Product Brochure, “KEN AL10, Automated load carrier for instrument trolleys in CSSD departments,” 2017.

* cited by examiner

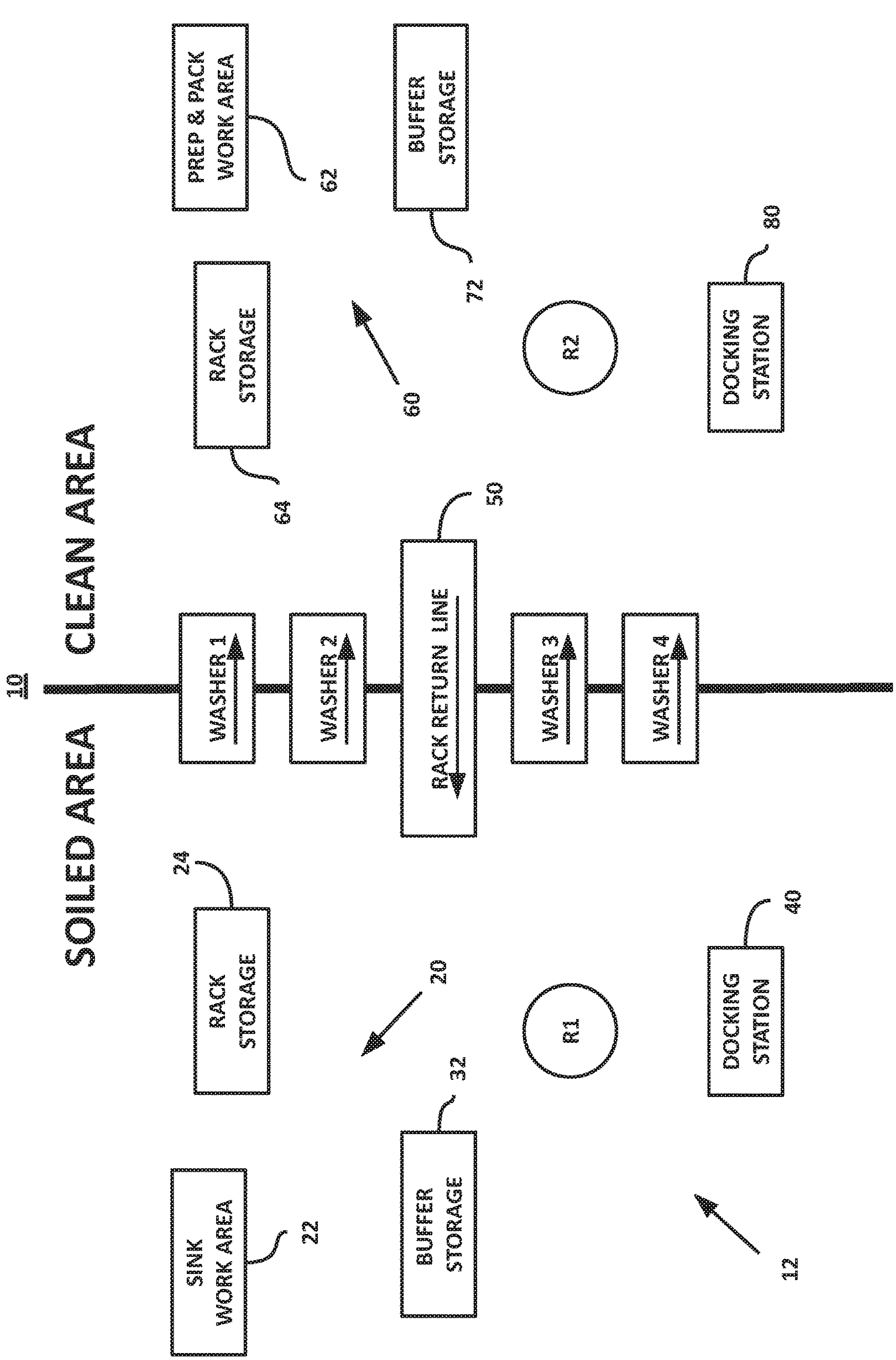

10
SOILED AREA
CLEAN AREA
PREP & PACK WORK AREA
62
BUFFER STORAGE
72
RACK STORAGE
64
60
R2
DOCKING STATION
80
WASHER 1
WASHER 2
RACK RETURN LINE
50
WASHER 3
WASHER 4
RACK STORAGE
24
20
R1
DOCKING STATION
40
BUFFER STORAGE
32
SINK WORK AREA
22
12

FIG. 1

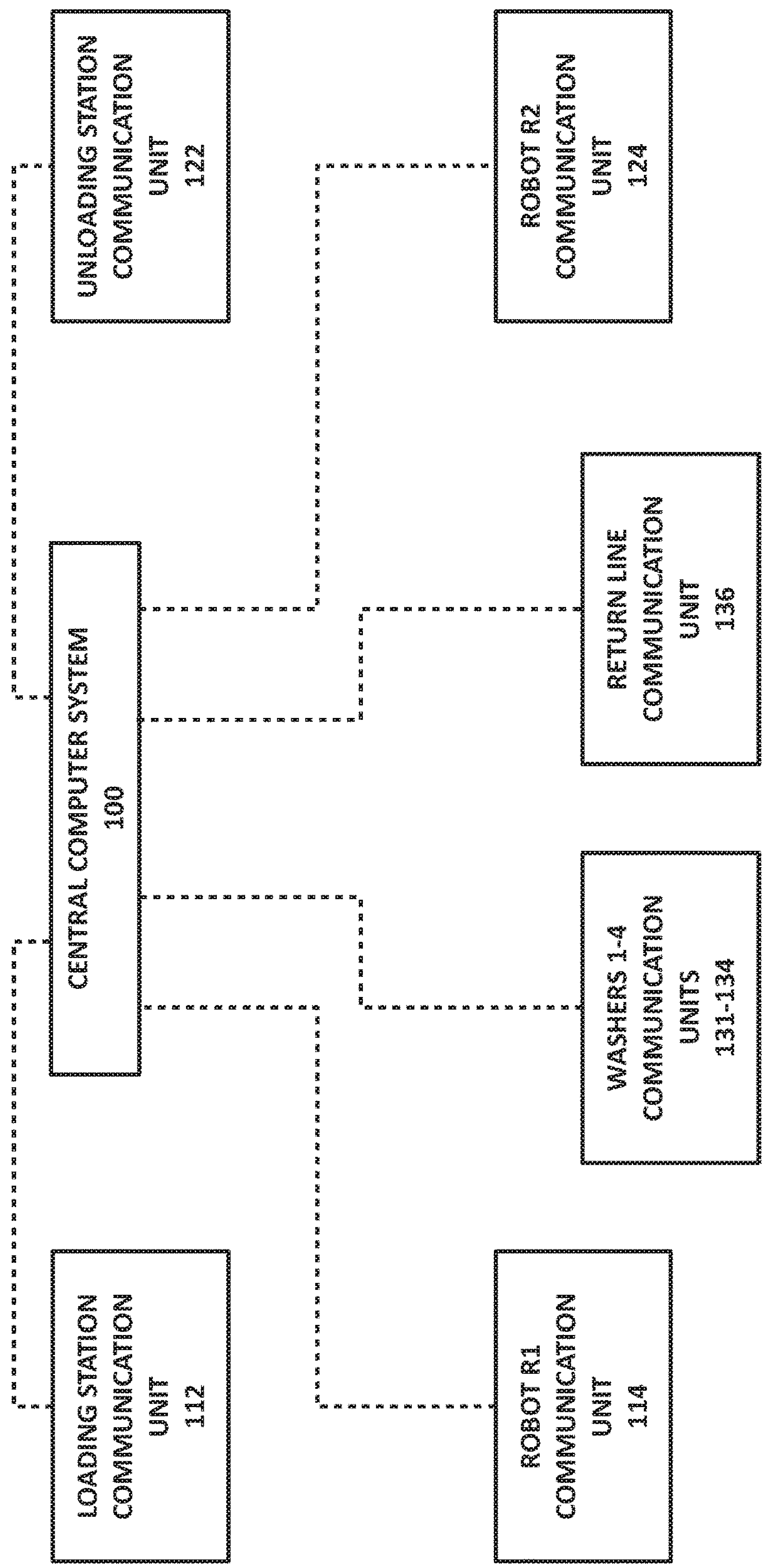

UNLOADING STATION COMMUNICATION UNIT 122
ROBOT R2 COMMUNICATION UNIT 124
CENTRAL COMPUTER SYSTEM 100
RETURN LINE COMMUNICATION UNIT 136
WASHERS 1-4 COMMUNICATION UNITS 131-134
LOADING STATION COMMUNICATION UNIT 112
ROBOT R1 COMMUNICATION UNIT 114

FIG. 2

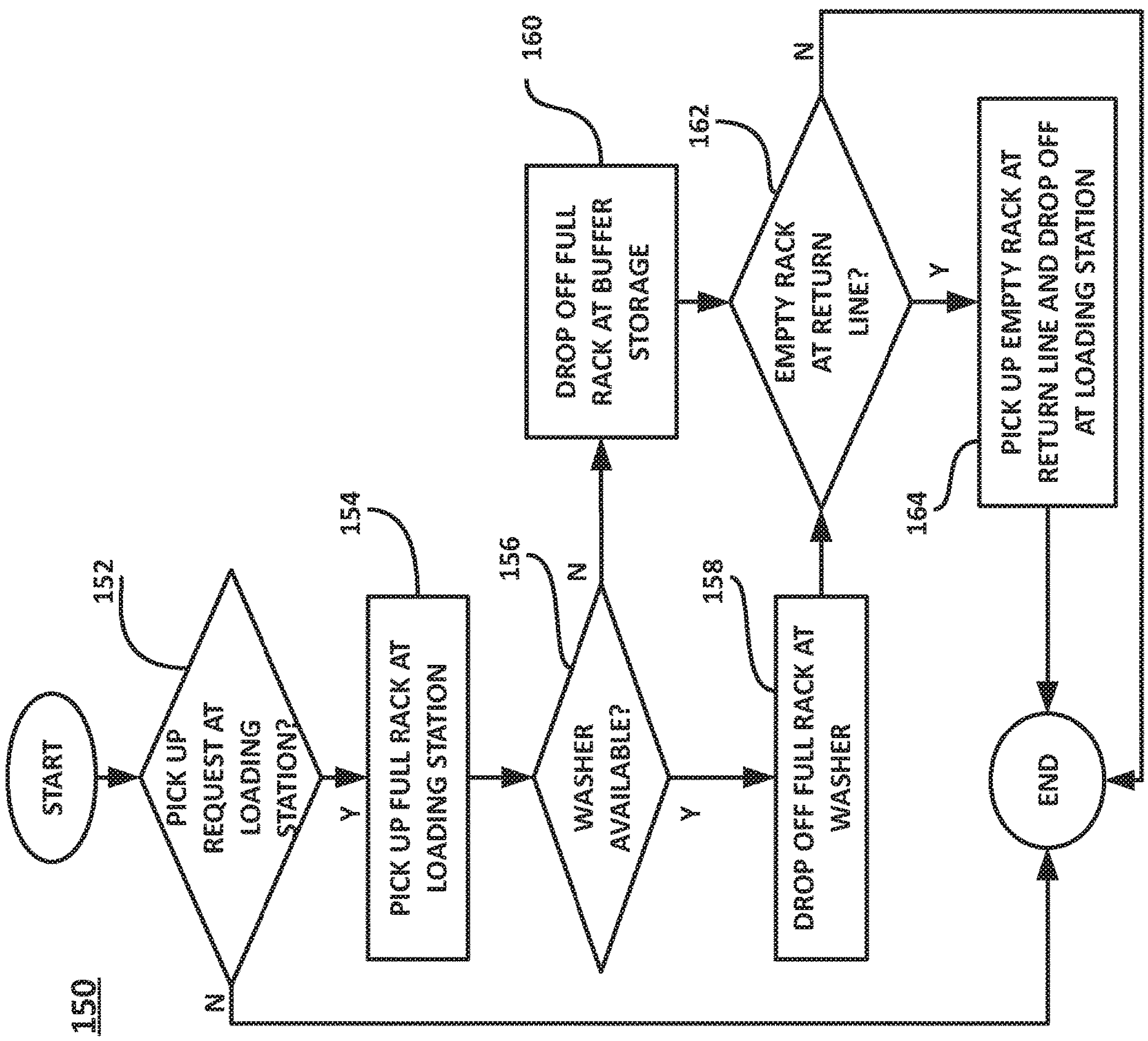

150
START
152
PICK UP REQUEST AT LOADING STATION?
Y
N
154
PICK UP FULL RACK AT LOADING STATION
156
WASHER AVAILABLE?
Y
N
158
DROP OFF FULL RACK AT WASHER
160
DROP OFF FULL RACK AT BUFFER STORAGE
162
EMPTY RACK AT RETURN LINE?
Y
N
164
PICK UP EMPTY RACK AT RETURN LINE AND DROP OFF AT LOADING STATION
END

FIG. 3

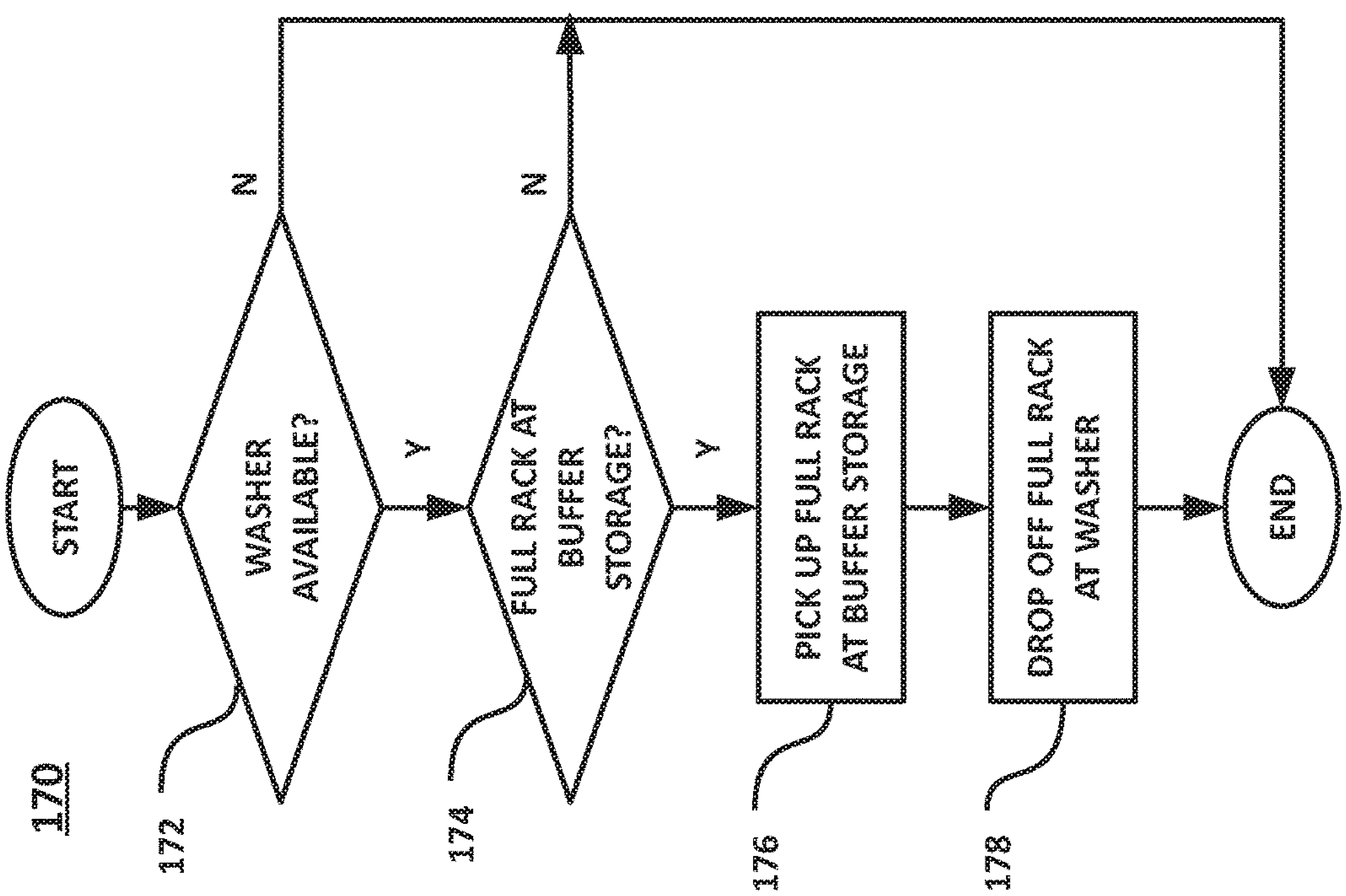

170
START
WASHER AVAILABLE?
172
Y
N
FULL RACK AT BUFFER STORAGE?
174
Y
N
PICK UP FULL RACK AT BUFFER STORAGE
176
DROP OFF FULL RACK AT WASHER
178
END

FIG. 4

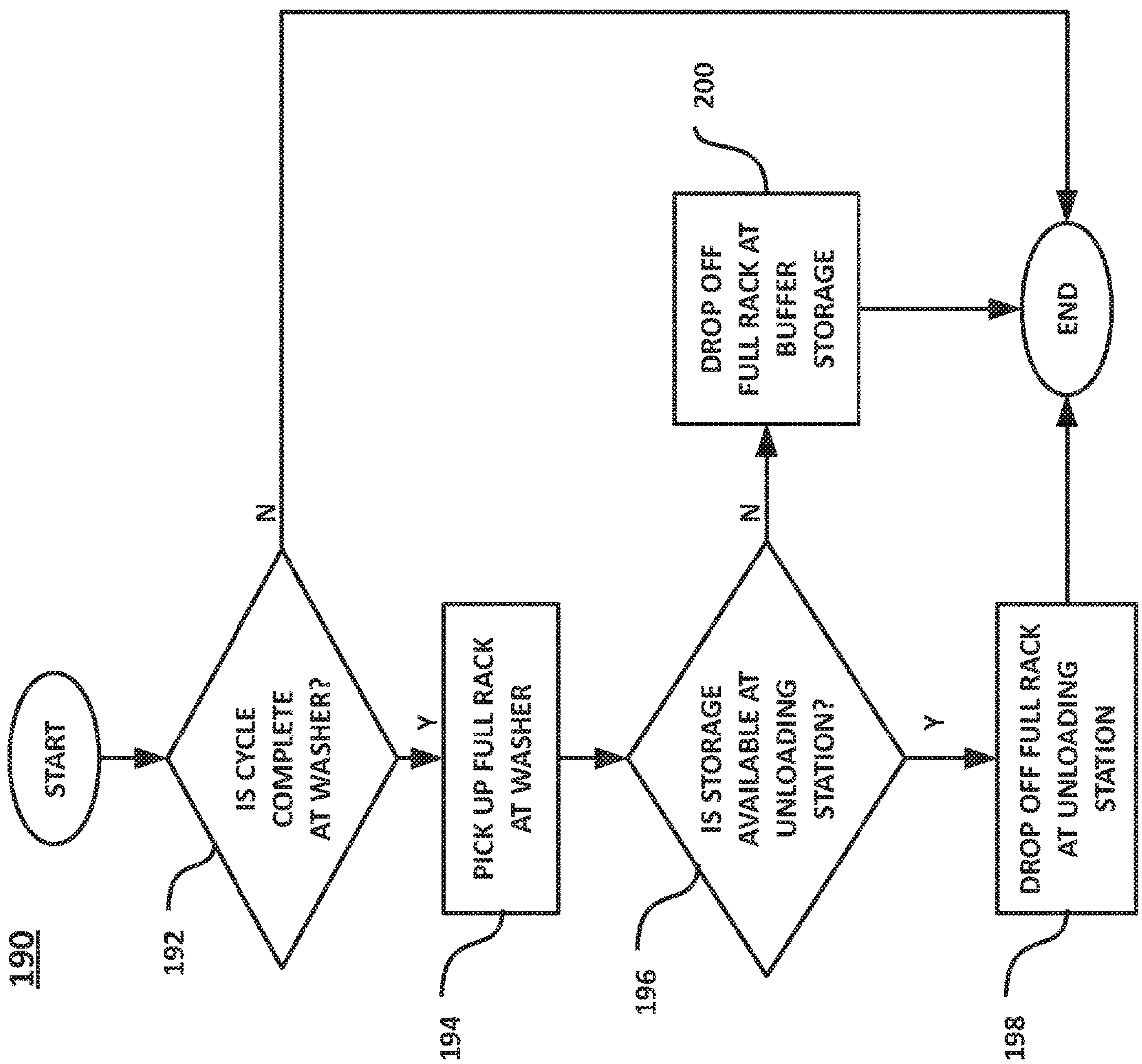

190
START
192
IS CYCLE COMPLETE AT WASHER?
N
Y
194
PICK UP FULL RACK AT WASHER
196
IS STORAGE AVAILABLE AT UNLOADING STATION?
N
Y
198
DROP OFF FULL RACK AT UNLOADING STATION
200
DROP OFF FULL RACK AT BUFFER STORAGE
END

FIG. 5

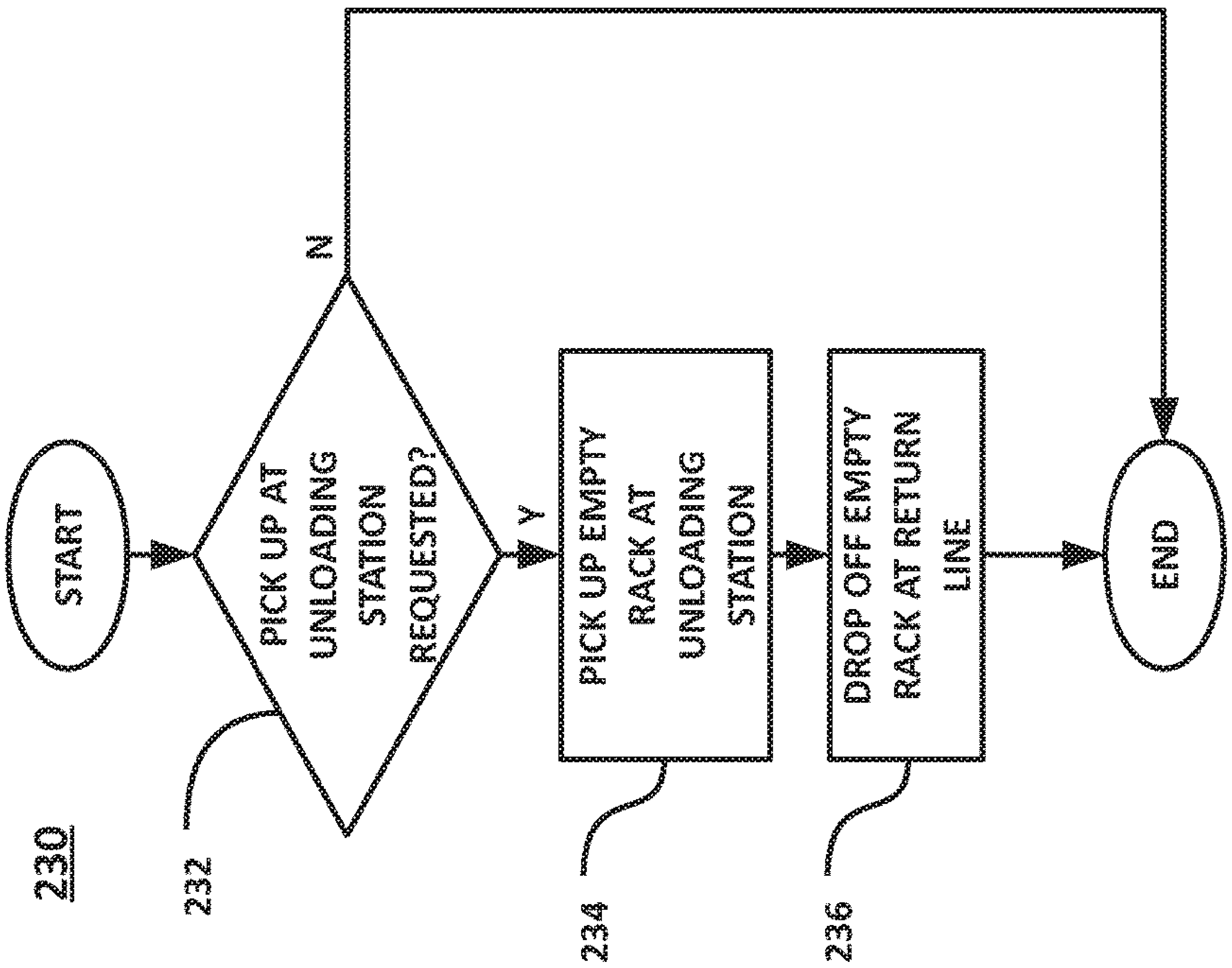

230
START
PICK UP AT UNLOADING STATION REQUESTED?
232
N
Y
PICK UP EMPTY RACK AT UNLOADING STATION
234
DROP OFF EMPTY RACK AT RETURN LINE
236
END

FIG. 7

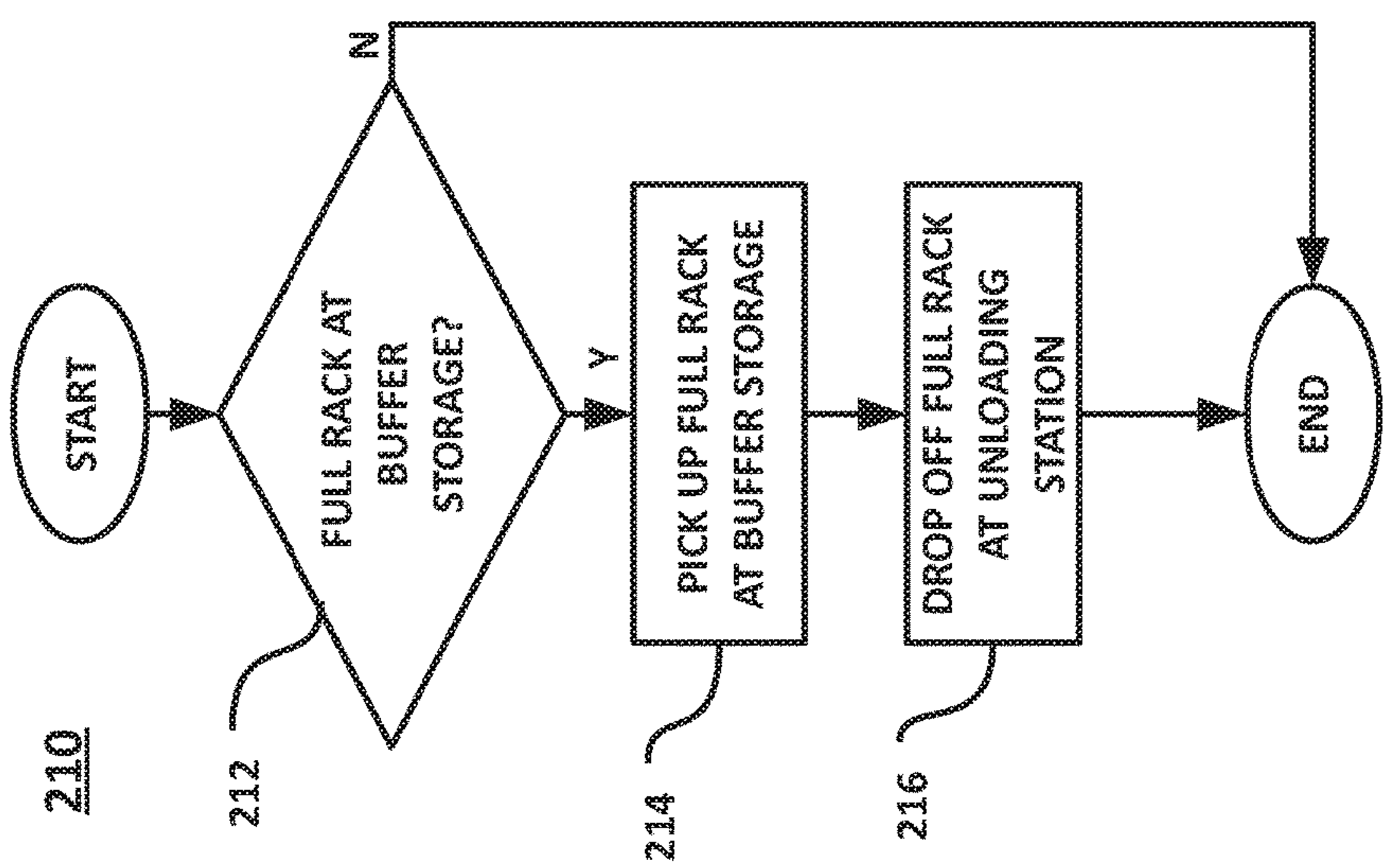

210
START
FULL RACK AT BUFFER STORAGE?
212
N
Y
PICK UP FULL RACK AT BUFFER STORAGE
214
DROP OFF FULL RACK AT UNLOADING STATION
216
END

FIG. 6

ROBOT-BASED RACK PROCESSING SYSTEM

FIELD OF THE INVENTION

The present invention relates to a robot-based system for processing racks used for transportation of articles in connection with an inactivation procedure, such as a sterilization, disinfection, or decontamination process.

BACKGROUND OF THE INVENTION

In many healthcare facilities (e.g., hospitals), a central sterilization services department (CSSD) is responsible for carrying out inactivation procedures (e.g., sterilization, disinfection, and decontamination) on medical utensils, surgical instruments, and other articles found in the healthcare facility (collectively referred to herein as "medical instruments"). The workspace for a conventional CSSD is physically arranged such that there is (i) a soiled area and (ii) a clean area which is isolated from the soiled area. Soiled medical instruments are loaded into an inactivation apparatus (such as a disinfector/washer or sterilizer) in the soiled area, and the processed medical instruments are unloaded from the inactivation apparatus in the clean area.

A rack (e.g., a manifold rack) is used to facilitate transportation and processing of the medical instruments within the workspace of the CSSD. At a first location (within the soiled area), soiled medical instruments are loaded onto a rack. Subsequently, the full rack is moved to a second location (within the soiled area) for loading into an inactivation apparatus. When the inactivation procedure is completed, the full rack is unloaded from the inactivation apparatus at a third location (within the clean area), and moved to a fourth location (within the clean area) where the medical instruments are unloaded from the rack. The empty rack is then returned to the soiled area for reuse.

In prior art rack processing systems used in connection with washers/disinfectors, it is known to use automation to load racks into the washer/disinfector and to unload racks from the washer/disinfector. However, in the prior art, transfer carts are used to manually transport racks between the location where racks are loaded with the soiled medical instruments and the location of an automated loader or conveyer used to load racks into the washer/disinfector. Transfer carts are also used by operators to manually transport a rack between the location of an automated unloader or conveyer that receives a rack unloaded from the washer/disinfector and the location where the medical instruments are unloaded from the rack.

The present invention overcomes these and other drawbacks of the prior art by providing a robot-based system for processing racks used for transportation of articles in connection with an inactivation procedure.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a rack processing system for processing racks in a workspace having a soiled area and a clean area isolated from the soiled area, the rack processing system comprising: at least one inactivation apparatus for carrying out an inactivation procedure, said inactivation apparatus loaded in the soiled area and unloaded in the clean area; a first robot located in the soiled area for transporting a rack loaded with soiled medical instruments from a first location in the soiled area to the at least one inactivation apparatus; a second robot located in the clean area for transporting a rack loaded with clean medical instruments from the at least one inactivation apparatus to a second location in the clean area; and a central computer system for providing instructions to the first and second robots.

In accordance with another aspect of the present invention, there is provided a method for processing racks in a workspace having a soiled area and a clean area isolated from the soiled area, the method comprising: transmitting a pick up request from a loading station to a central computer system, the pick up request requesting pick up of a full rack from the loading station; and determining whether an inactivation apparatus is available for processing a rack, wherein if an inactivation apparatus is available, then transmitting instructions from the central computer system to a first robot located in the soiled area to pick up the full rack from the loading station and transport it to the available inactivation apparatus, and if the inactivation apparatus is not available, then transmitting instructions from the central computer system to the first robot to pick up the full rack from the loading station and transport it to a first buffer storage.

An advantage of the present invention is the provision of a rack processing system having greater levels of automation.

Another advantage of the present invention is the provision of a rack processing system having improved logistics.

Still another advantage of the present invention is the provision of a rack processing system that provides faster and more efficient processing.

A still further advantage of the present invention is the provision of a rack processing system that can reduce injury risk to the operator.

Yet another advantage of the present invention is the provision of a rack processing system that integrates use of autonomously guided vehicles for transport of racks within a workspace.

These and other advantages will become apparent from the following description of illustrated embodiments taken together with the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may take physical form in certain parts and arrangement of parts, an embodiment of which will be described in detail in the specification and illustrated in the accompanying drawings which form a part hereof, and wherein:

FIG. **1** is a block diagram of a workspace for a robot-based rack processing system, according to an embodiment of the present invention;

FIG. **2** is a block diagram of a central computer system of the rack processing system as linked to several associated communication units, according to an embodiment of the present invention;

FIG. **3** is a flow diagram illustrating a pre-wash pick up routine, according to an embodiment of the present invention;

FIG. **4** is a flow diagram illustrating a washer load routine, according to an embodiment of the present invention;

FIG. **5** is a flow diagram illustrating a washer unload routine, according to an embodiment of the present invention;

FIG. **6** is a flow diagram illustrating a buffer storage unload routine, according to an embodiment of the present invention; and

FIG. **7** is a flow diagram illustrating an unloading station pick up routine, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings wherein the showings are for the purposes of illustrating an embodiment of the present invention only and not for the purposes of limiting same, FIG. **1** shows a block diagram of a workspace **10** for a robot-based rack processing system **12**, according to an embodiment of the present invention. Workspace **10** is divided into a soiled area and a clean area that is isolated from the clean area by a wall or other barrier.

It should be appreciated that the present invention is described herein with reference to a disinfection procedure that uses washer/disinfectors as the disinfection apparatus, as will be described below. However, this illustrated embodiment of the present invention is not intended to limit same. Thus, it is contemplated that other types of inactivation apparatus may be substituted for the washer/disinfectors of the illustrated embodiment, including, but not limited to, a sterilization apparatus. Moreover, the operations described herein as pre-wash and post-wash may be other types of processing steps taken before and after a different inactivation procedure (e.g., sterilization).

In the soiled area of workspace **10**, system **12** is generally comprised of a loading station **20**, a buffer storage **32**, a docking station **40**, and a robot R**1**. Loading station **20** includes a sink work area **22** and a rack storage **24**. In the clean area of workspace **10**, system **12** is generally comprised of an unloading station **60**, a buffer storage **72**, a docking station **80**, and a robot R**2**. Unloading station **60** includes a preparation and packaging ("prep & pack") work area **62** and a rack storage **64**.

System **12** also includes one or more inactivation apparatus and a rack return line **50**. A loading side of the inactivation apparatus is located in the soiled area, and an unloading side of the inactivation apparatus is located in the clean area. In the illustrated embodiment, the inactivation apparatus takes the form of washers **1**-**4**, which are conventional washer/disinfectors which both wash and disinfect medical instruments. For example, the washer/disinfectors may be Reliance® or AMSCO® brand washer/disinfectors from STERIS. A loading side of the rack return line **50** is located in the clean area and an unloading side of rack return line **50** is located in the soiled area. In the illustrated embodiment, rack return line **50** takes the form of a conventional conveyor system.

Loading station **20**, buffer storage **32**, docking station **40**, washers **1**-**4**, and rack return line **50** are locations between robot R**1** moves to deliver and retrieve racks, as will be described in detail below. It is contemplated that robot R**1** may travel to additional locations within the soiled area that are not shown in the illustrated embodiment.

Referring now to the soiled area of workspace **10**, loading station **20** is a location where an operator performs pre-wash operations to process soiled medical instruments. Sink work area **22** includes one or more washing sinks. Rack storage **24** is a structure for storing (i) empty racks that are to be filled by an operator with pre-washed medical instruments and (ii) storing racks that have been filled by an operator with pre-washed medical instruments to be processed by a washer. In the illustrated embodiment, rack storage **24** may take the form of one or more tables located proximate to washing sinks in sink work area **22**. Buffer storage **32** provides temporary storage for full racks that are awaiting loading into a washer. In the illustrated embodiment, buffer storage **32** may take the form of one or more tables or shelves.

In the illustrated embodiment, robot R**1** is an autonomous guided vehicle (AGV), such as the Adept Lynx™ self-navigating autonomous indoor vehicle (AIV) from Omron Adept Technologies, Inc. The Adept Lynx™ includes a controller, a user interface (e.g., touchscreen interface), an electric motor locomotion system, an on-board power supply (22-29 VDC power pack), power management, I/O for wireless communication, sensors, lasers support, and a programmable navigation system for navigating through the use of a stored digital map. Robot R**1** can use the digital map to avoid traveling into regions within workspace **10**, such as a region proximate to a washer undergoing maintenance. For example, Robot R**1** can be programmed to prevent entry into certain prohibited regions within workspace **10**.

In the illustrated embodiment, robot R**1** may be adapted to include a computer controlled payload handling system to facilitate the handling, loading, and unloading of racks from robot R**1**. The handling system includes a support platform for supporting a rack on robot R**1**; an alignment system for precise alignment of robot R**1** at a target location; a lift system for adjusting the vertical position of the support platform; and a pusher/puller system for "pushing" a rack off of the support platform and for "pulling" a rack onto the support platform. The lift system is comprised of a motor (e.g., servomotor), a scissor lift assembly, and a limit switch. The pusher/puller system is comprised of a motor (e.g., servomotor), an actuator (e.g., a solenoid), and a limit switch. The alignment system includes one or more proximity sensors and one or more lasers.

The handling system operates in the following manner. The laser is used to detect the center position of a goal (e.g., the loading-side or unloading-side opening of a washer) using a target. The target may take the form of a vertical narrow reflector strip that reflects the laser beam while robot R**1** is turning a few degrees for a laser scan. Robot R**1** turns in order to accurately align with the center position of the goal. The robot then moves forward toward the goal until the proximity sensors detect contact with the surface of the goal. Once robot R**1** has reached the goal, the height of the support platform is adjusted by the lift system using the same laser beam. In this regard, the lift system increases the height of the support platform, until it detected that the laser beam has reached the top of the reflector strip.

In accordance with an embodiment of the present invention, the support platform includes a sensor and a plunger. The plunger holds the rack in place during movement of the robot, and the sensor detects whether the rack has been successfully loaded onto the support platform.

Robot R**1** may also include a fluid collection system that includes a fluid collection reservoir (e.g., drip pan) and an electronically actuated drain valve. The fluid collection reservoir collects water that drips off the racks transported by robot R**1**. For example, water or condensate may be on the surface of the racks as a result of the washing/disinfection process. The drain valve is opened to empty the fluid collection reservoir. The fluid collection system may also include a level detector for detecting the fluid level within the fluid collection reservoir. The level detector alerts the control system of robot R**1** that the fluid collection reservoir needs to be purged. This information can also be communicated to a central computer system **100**, described below.

Docking station **40** serves as a recharging station that provides power for recharging a battery of robot R**1**. In the illustrated embodiment, docking station **40** may also include a floor drain or a collection vessel for receiving fluid emptied from the fluid collection reservoir of robot R**1**.

Referring now to the clean area of workspace **10**, unloading station **60** is a location where an operator performs post-wash operations. At prep & pack work area **62**, an operator unloads clean medical instruments from a rack, inspects the medical instruments, and sort the medical instruments into organized trays. The organized trays may be stored in a cooling storage unit (not shown). Rack storage **64** is a structure for storing (i) full racks that have been removed from a washer and are to be processed by an operator and (ii) racks that have been emptied by an operator and are awaiting return to the soiled area. In the illustrated embodiment, rack storage **64** may take the form of one or more tables located proximate to prep & pack work area **62**. Buffer storage **72** provides temporary storage for full racks that have been removed from a washer. In the illustrated embodiment, buffer storage **32** may take the form of one or more tables or shelves.

Unloading station **60**, buffer storage **72**, docking station **80**, washers **1-4**, and rack return line **50** are locations between robot R**2** moves to deliver and retrieve racks, as will be described in detail below. It is contemplated that robot R**2** may travel to additional locations within the clean area that are not shown in the illustrated embodiment.

Robot R**2** is substantially the same as robot R**1** described above. Likewise, docking station **80** is substantially the same as docking station **40** described above.

It should be appreciated that while the illustrated embodiment of the present invention has only a single robot in the soiled and clean areas, it is contemplated that a more than one robot may be located in the soiled and clean areas.

System **12** also includes central computer system **100**, as shown in FIG. **2**. Communication units located within the soiled and clean areas allow for bi-directional data communication with central computer system **100**. Communication between central computer system **100** and the communication units may include the use wired and/or wireless communication systems (e.g., Ethernet, TCP/IP, Wi-Fi, etc.).

In the illustrated embodiment, loading station communication unit **112** and unloading station communication unit **122** include a user interface for an operator to request a rack pick up or delivery. For example, a tablet computer device may serve as communication units **112** and **122**. Robot R**1** includes communication unit **114** and robot R**2** includes communication unit **124**. Washers **1-4** include communication units **131-134** to provide status information to the central computer system **100** (e.g., ready for loading, busy, and cleaning cycle complete) and to receive instructions from central computer system **100** (e.g., open door at soiled-side for loading, and open door at clean-side for unloading), and rack return line **50** includes communication unit **136** to provide status information (e.g., rack awaiting pick up at soiled-side).

In an embodiment of the present invention, the racks of system **12** may include a machine-readable code (e.g., bar code or RFID tag) that can be scanned. The machine-readable code can uniquely identify each rack and/or identify a rack type (e.g., 2-level rack, 5-level rack, multi-function rack, special purpose rack, etc.). Each washer **1-4** may include a scanner to scan each rack that is loaded into the washer. The information about the scanned rack is communicated by washers **1-4** (via communication units **131-134**) to central computer system **100**. Information about the scanned rack can be used by the washer to determine a suitable cleaning cycle for the rack. Rack return line **50** may also include a scanner to scan each rack that is returned from the clean area to the soiled area. Information about each rack is communicated by return line **50** (via communication unit **136**) to central computer system **100**. Accordingly, central computer system **100** can prioritize a rack pick up at return line **50** (soiled area) based upon a requested rack type. It is also contemplated that robots R**1** and R**2** may include scanners to scan racks, and provide information about the racks to central computer system **100**.

Basic operation of robot-based rack processing system **10**, according to an embodiment of the present invention, will now be summarized in connection with rack processing in the soiled and clean areas.

Soiled Area

1) An operator at loading station **20** sends instructions to central computer system **100** requesting pick up of a full rack loading station **20**, and delivery of an empty rack to loading station **20**.
2) Robot R**1** receives instructions from central computer system **100** to pick up the full rack at loading station **20**, and delivery the full rack to an available washer. If no washers are currently available, then robot R1 delivers the full rack to buffer storage **32** for temporary storage until a washer becomes available.
3) Robot R**1** receives instructions from central computer system **100** to pick up an empty rack from the rack return line **50** and deliver the empty rack to loading station **20**.

Clean Area

1) An operator at unloading station **60** sends instructions to central computer system **100** requesting pick up of an empty rack at unloading station **60**, and delivery of a (clean) full rack to unloading station **60**.
2) Robot R**2** receives instructions from central computer system **100** to pick up an empty rack from unloading station **60** and deliver the empty rack to rack return line **50** for return to the soiled area of workspace **10**.
3) Robot R**2** receives instructions from central computer system **100** to pick up the (clean) full rack at one of the washers, and deliver the full rack to unloading station **60**. If no space is available at unloading station **60**, then robot R**2** delivers the full rack to buffer storage **72** for temporary storage until space becomes available at unloading station **60**.

Detailed operation of robot-based rack processing system **12** will now be described with reference to FIGS. **3-7**, which respectively illustrate flow diagrams for a pre-wash pick up routine **150**, a washer load routine **170**, a washer unload routine **190**, a buffer storage unload routine **210**, and an unloading station pick up routine **230**.

FIG. **3** shows a flow diagram for pre-wash pick up routine **150** (soiled area). This routine involves pick up of a full rack from loading station **20**, drop off of the full rack at an available washer or at buffer storage **32**, and drop off of an empty rack (returned from the clean area) at loading station **20**. First, it is determined whether an operator at loading station **20** has made a pickup request by sending instructions to central computer system **100** (step **152**). If a pickup request has been made, then central computer system **100** sends instructions to robot R1 to pick up a full rack at loading station **20** (step **154**). The computer system **100** determines whether any washers are available (step **156**). If it is determined that no washers are available, then central computer system **100** sends instructions to robot R1 to drop off the full rack at buffer storage **32**. If it is determined that a washer is available, then central computer system **100** sends instructions to robot R1 to drop off the full rack at the available washer (step **158**). Following the step of dropping off the full rack at a washer (step **158**) or the step of dropping off the full rack at buffer storage **32** (step **160**), central computer system **100** determines whether there is an empty rack ready for pick up at return line **50** to replace the full rack that was retrieved from loading station **20** (step **162**). If it is determined that there is an empty rack awaiting pick up at return line **50**, then central computer system **100** sends instructions to robot R**1** to pick up the empty rack at return line **50** and drop it off at loading station **20** (step **164**). If it is determined that there is no empty rack at return line **50**, then the pre-wash pick up routine ends.

In one embodiment of the present invention, central computer system **100** randomly selects an available washer for loading with a full rack. In an alternative embodiment, central computer system **100** selects a washer that is most suitable for the type of rack.

FIG. **4** shows a flow diagram for the washer load routine **170** (soiled area). This routine involves pick up of full rack stored at buffer storage **32** and drop off at an available washer. Central computer system **100** determines whether a washer is available (step **172**). If no washer is available, then washer load routine **170** ends. If a washer is available, then it is determined whether there is a full rack awaiting pick up at buffer storage **32** (step **174**). If there is no full rack awaiting pick up at buffer storage **32**, then washer load routine **170** ends. If there is a full rack awaiting pickup a buffer storage **32**, then central computer system **100** sends instructions to robot R**1** to pick up a full rack at buffer storage **32** (step **176**) and drop off the full rack at the available washer (step **178**).

FIG. **5** shows a flow diagram for the washer unload routine **170** (clean area). This routine involves pick up of a full rack at a washer and drop off of the full rack at unloading station **60** or at buffer storage **72**. Central computer system **100** determines if a cleaning cycle is completed at one of the washers **1**-**4** (step **192**). If none of the washers are ready for a pick up, then the washer unload routine **190** ends. If one of the washers **1**-**4** is ready for a pickup, then central computer system **100** sends instructions to robot R**2** to pick up a full rack at the washer (step **194**). Central computer system **100** determines whether any storage is available at unloading station **60**. If storage is available, then central computer system **100** sends instructions to robot R**2** to drop off the full rack at unloading station **60**. If no storage is available at unloading station **60**, then central computer system **100** sends instructions to robot R**2** to drop off the full rack at buffer storage **72** (step **200**).

FIG. **6** shows a flow diagram for the buffer storage unload routine **210** (clean area). This routine involves pick up of a full rack at buffer storage **72** and drop off of the full rack at unloading station **60**. Central computer system **100** determines if a full rack is awaiting pickup at buffer storage **72** (step **212**). If no full rack is awaiting pickup, then buffer storage unload routine **210** ends. If a full rack is awaiting pickup, then central computer system **100** sends instructions to robot R**2** to pick up the full rack at buffer storage **72** (step **214**) and drop off the full rack at unloading station **60** (step **216**).

FIG. **7** shows a flow diagram for the unloading station pick up routine **230** (clean area). This routine involves pick up of an empty rack at unloading station **60** and drop off of the empty rack at return line **50**. Central computer system **100** determines whether an operator has made a request for a pickup at unloading station **60** (step **232**). If a pickup request has been made, then central computer system **100** sends instructions to robot R**2** to pick up the empty rack at unloading station **60** (step **234**) and drop off the empty rack at return line **50** (step **236**). If no pickup request has been made by an operator, then unloading station pick up routine **230** ends.

In one embodiment of the present invention, the instructions sent to central computer system **100** by the operator to request pick up of a full rack at loading station **20** may include (i) a priority level to identify a priority for the requested pick up of the full rack, and/or (ii) a rack-type to identify the type of empty rack that is to be delivered to loading station **20** to replace the full rack being picked up. In one embodiment of the present invention, priority levels are represented by a value from 1 to 100, where 1 is normal priority and 100 is highest priority.

It is also contemplated that a priority level and/or a rack-type may be determined by central computer system **100** for complete processing by system **12**. For example, priority level and rack-type may be determined according to a list of surgery requests entered into central computer system **100**. Therefore, depending on the type of surgeries scheduled for the day, certain medical instruments may need to be processed by the washers faster than others in order to be available for use in the next scheduled surgery. This priority level selection allows a high priority level to be associated with a particular rack type.

The foregoing describes specific embodiment of the present invention. It should be appreciated that these embodiments are described for purposes of illustration only, and that numerous alterations and modifications may be practiced by those skilled in the art without departing from the spirit and scope of the invention. It is intended that all such modifications and alterations be included insofar as they come within the scope of the invention as claimed or the equivalents thereof.

Other modifications and alterations will occur to others upon their reading and understanding of the specification. It is intended that all such modifications and alterations be included insofar as they come within the scope of the invention as claimed or the equivalents thereof.

Having described the invention, the following is claimed:

1. A rack processing system for processing racks in a workspace having a soiled area and a clean area isolated from the soiled area, the rack processing system comprising:

a loading station in the soiled area for loading racks with soiled medical instruments;

a first buffer storage in the soiled area for storing racks loaded with soiled medical instruments;

at least one inactivation apparatus for carrying out an inactivation procedure on racks loaded with soiled medical instruments, said inactivation apparatus is a washer/disinfector or a sterilizer having a loading side in the soiled area and an unloading side in the clean area;

a rack return line including a conveyer for returning racks from the clean area to the soiled area, said rack return line having a loading side in the clean area and an unloading side in the soiled area;

a first robot located in the soiled area for transporting racks between a plurality of locations that include: (i) the loading station, (ii) the first buffer storage, (iii) the inactivation apparatus, and (iv) the rack return line;

an unloading station in the clean area for unloading medical instruments from racks processed by the inactivation apparatus;

a second buffer storage in the clean area for storing racks loaded with medical instruments processed by the inactivation apparatus;

a second robot located in the clean area for transporting racks between a plurality of locations that include: (i) the inactivation apparatus, (ii) the unloading station, (iii) the second buffer storage, and (iv) the rack return line; and

a central computer system for providing instructions to the first and second robots, the central computer system programmed to:

(a) receive a pick up request from the loading station requesting pick up of a rack from the loading station, and determine whether an inactivation apparatus is available for processing the rack, wherein

if the inactivation apparatus is available, the central computer system programmed to transmit instructions to the first robot to pick up the rack from the loading station and transport the rack to the inactivation apparatus that is available, and

if the inactivation apparatus is not available, the central computer system programmed to transmit instructions to the first robot to pick up the rack from the loading station and transport the rack to the first buffer storage; and

(b) receive status information indicating whether the inactivation apparatus has completed a processing cycle, and determine whether storage is available at the unloading station, wherein

if the processing cycle of the inactivation apparatus is complete and storage is available at the unloading station, then the central computer system programmed to transmit instructions from the central computer system to the second robot to pick up the rack from the inactivation apparatus and transport the rack to the unloading station, and

if the processing cycle of the inactivation apparatus is complete and storage is not available at the unloading station, then the central computer system programmed to transmit instructions from the central computer system to the second robot to pick up the rack from the inactivation apparatus and transport the rack to the second buffer storage.

2. The rack processing system of claim **1**, wherein the system further comprises a first docking station in the soiled area for recharging the first robot.

3. The rack processing system of claim **1**, wherein the system further comprises a second docking station in the clean area for recharging the second robot.

4. The rack processing system of claim **1**, wherein the central computer system is programmed to determine whether an inactivation apparatus is available for processing a rack and whether a rack is located at the first buffer storage, wherein

if the inactivation apparatus is determined to be available and the rack is located at the first buffer storage, said central computer system programmed to transmit instructions to the first robot to pick up the rack from the first buffer storage and transport to the available inactivation apparatus.

5. The rack processing system of claim **1**, wherein the central computer system is programmed to determine whether a full rack is located at a second buffer storage, wherein if the full rack is located at the second buffer storage, said central computer system programmed to transmit instructions to the second robot to pick up the full rack from the second buffer storage and transport the full rack to the unloading station.

6. The rack processing system of claim **1**, wherein the central computer system is programmed to determine whether a request has been received from the unloading station for a pick up of an empty rack at the unloading station, wherein if the request has been received from the unloading station, said central computer system programmed to transmit instructions to the second robot to pick up the empty rack at the unloading station and transport the empty rack to the return line for returning the empty rack to the soiled area.

* * * * *